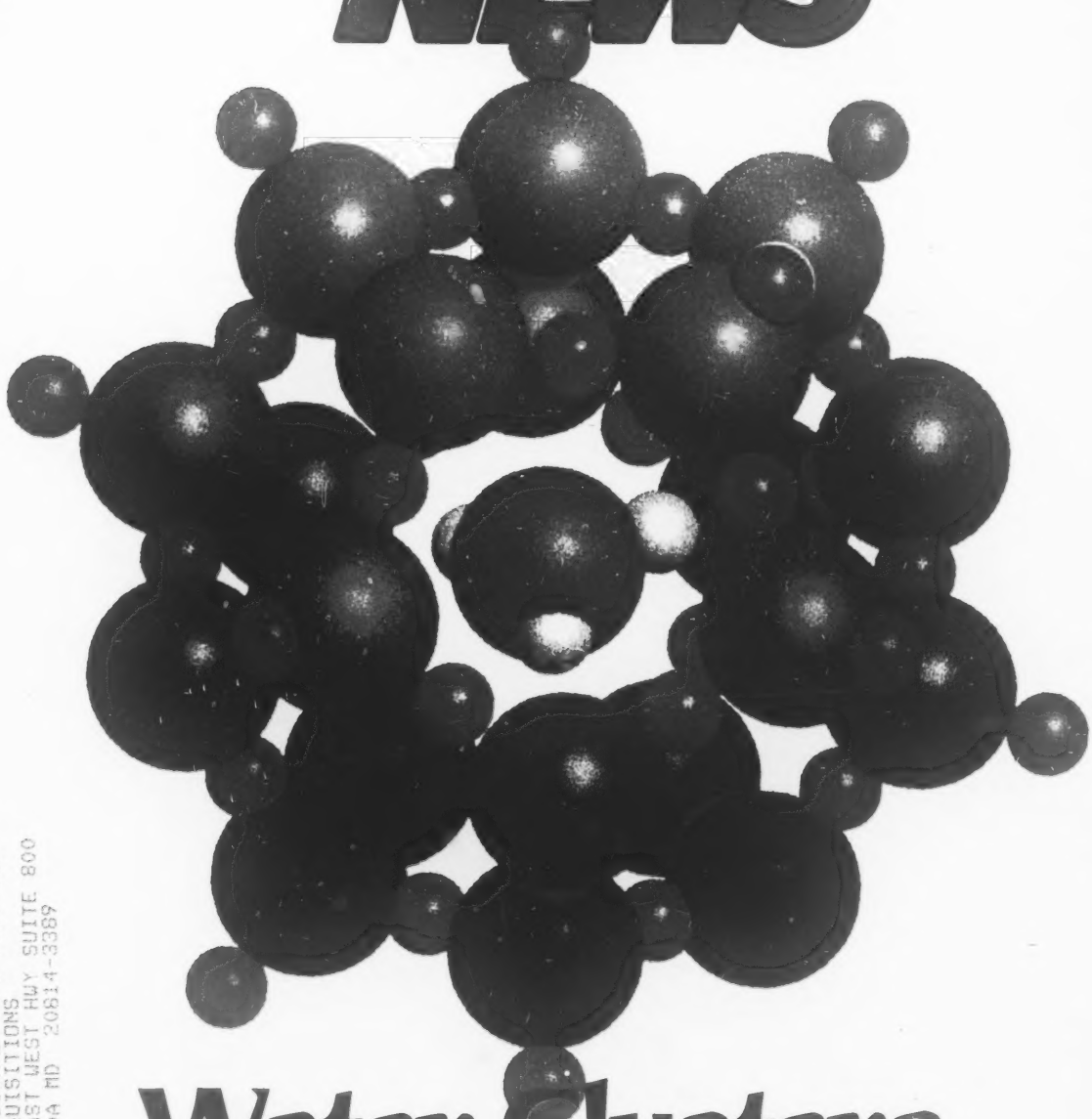
APRIL 8, 1991

CHEMICAL & ENGINEERING

Top 50 chemical products
Page 13

NEWS



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Water Clusters

Researchers probe architecture and stability

Page 47

CHEMICAL & ENGINEERING NEWS

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APRIL 8, 1991

News of the Week

■ **International companies and industrial organizations meeting this week in the Netherlands will take pledge of environmental responsibility.** Page 4

■ **Elsevier buys Pergamon Press, consolidating two big scientific publishers.** Page 5

■ **Himont chairman Alexander F. Giacco starts $200 million venture in plastics with two top executive partners.** Page 5

■ **Erythromycin derivative with increased stability under acidic conditions is produced by target mutagenesis.** Page 6

■ **Rohm & Haas chairman J. Lawrence Wilson speaks on recruitment and hiring of blacks to black chemists and chemical engineers meeting last week in Washington, D.C.** Page 6

Cover: A computer-generated model of the structure of the water cluster $H^+(H_2O)_{21}$, shows the H_3O^+ ion encaged inside the pentagonal dodecahedron. The red balls represent nonhydrogen-bonded atoms. The small green balls are the hydrogen-bonded hydrogen atoms. The large balls are the oxygen atoms. Photo courtesy of A. Welford Castleman Jr., Pennsylvania State University

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Business

Top 50 chemicals recovered in 1990 from significant slowdown in 1989, rising 2% to an all-time high of 626 billion lb; overall output of polymers increased 4.3% in 1990 to a record 61.6 billion lb; petroleum refiners call for increased "environmental literacy" to meet environmental challenges of the 1990s; plastics industry offers major recycling plan in attempt to develop realistic solutions to disposal. Page 13

Government

Tacrine, a potential Alzheimer's treatment, stirs controversy as it wends its way through FDA's approval process; Margot O'Toole, whose allegations triggered a major scientific misconduct investigation, looks on as "Baltimore affair" nears end; discontent among academic researchers is at all-time high as they deal with issues of research ethics, funding, and technological competition. Page 30

Science/Technology

U.K.'s Royal Society of Chemistry celebrates 150th anniversary; 3-D structure of RNase H, key in life cycle of HIV, unraveled; thin films of fullerenes produced by doping. Page 50

Education

Analytical chemistry is no longer just for chemists at the University of Wisconsin, Madison, which has redefined it both to expand its horizons and attract nonchemistry majors. Page 63

Perkin Medal

Squibb's Miguel A. Ondetti, who led the group that discovered the hypertensive drug captopril, wins 1991 Perkin Medal. Page 64

Cover Story

Definitive evidence found for structure of 21-unit water cluster that contains hydronium ion at its core. Page 47

Chemical & Engineering News
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LETTERS

Ozone depletion

Your article on Union Carbide's new plants in Kingman, Ariz. (C&EN, Jan. 7, page 15) quotes Carbide plant manager, Frank Gasser, as saying to his citizen opponents, "If they promised not to maximize the dangers, . . . we wouldn't minimize the risks." Later, your writer says, "What has exasperated Carbide is the knowledge that CFC-12—as opposed to the more potent CFC-113 for example—is merely a minor player in the degradation of Earth's ozone layer." Far from being a minor player, CFC-12 is the most abundant chlorofluorocarbon in the atmosphere, the number one source of man-made chlorine in the stratosphere, and therefore a very major player in stratospheric ozone depletion.

Furthermore the ozone depletion potential of CFC-12 is actually somewhat greater than that of CFC-113 (e.g., 1.0 versus 0.82 in the Lawrence Livermore 1-D model).

F. Sherwood Rowland
Professor of Chemistry
University of California, Irvine

What is a chemical?

In some recent issues of C&EN there have been proposals to substitute innocuous terms for the word chemical, in order to improve the public opinion of chemistry. This strikes me as the confusion of image with reality that replaced War Department with Department of Defense.

Chemistry, in both academic research and industrial production, produces, concentrates, and releases into the environment unpleasant, dangerous chemicals. Calling them compounds or substances doesn't alter their impact on people's lives. If members of the public have never heard of beneficent man-made chemicals or harmful natural ones, whose fault is that? We are the experts, the teachers, and the teachers of teachers.

Marya Lieberman
Department of Chemistry
University of Washington, Seattle

Reduced grant awards

The Government Concentrates section (C&EN, Jan. 28, page 13) carried a report on the reduction in average grant length being implemented by the National Institutes of General Medical Science in response to the Congressional request that the National Institutes of Health develop a long-range plan for cost containment. In this same article, it was also reported that the institute is also eliminating the practice of downward negotiations, a euphemism that NIH had employed over the past several years to describe its yearly practice of unilaterally reducing the annual funding level of approved and funded continuing grants in order to accommodate annual fiscal budget constraints. Indeed, over the past several years these reductions have averaged 10 to 12% of the amounts originally approved and recommended by the relevant NIH institute and carried on the original grant award statement.

Unfortunately, while NIH has discontinued use of the term "downward negotiations," it has not abandoned the practice of reducing grant awards. Only the manner in which these reductions are presented has changed. NIH now proposes to limit annual increases in noncompeting awards to an average of 3 to 4%, using the actual fiscal-year 1990 award level as the new base. Since in almost all cases the 1990 award level already included a downward negotiation of 10 to 12%, the result of this announced policy change will be to make the previous administrative reductions permanent. The formulation of the plan is misleading as well as disingenuous in that it is intended to convey the impression to Congress and the scientific community that NIH has abandoned downward negotiations while doing exactly the opposite. Every principal investigator will still receive a net 10 to 12% reduction in 1991 and future years below the previously approved and recommended levels. If NIH feels compelled by the competing demands put on its budget to cut funded research grants across the board, it should state this clearly to the scientific community and to Congress. The appearance of articles such as that in C&EN only illustrates the early success it has had in distracting attention from what it is actually doing.

David E. Cane
Professor of Chemistry
Brown University

Corrections

- Nov. 26, 1990, page 54: The reference to the review of Paul Brodeur's book at the end of James Jauchem's letter to the editor should be Ashley, J. R., *IEEE Antennas & Propagation Soc. Mag.*, **32(2)**, 45 (1990).
- March 4, page 43: 3M Scotchweld AF 191 epoxy film adhesive has a service temperature up to 400 °F, not 300 °F.

Top 50 Chemicals Production Resumed Growth Last Year

Output increased 2% to an all-time high of 626 billion lb; organics production moved up 2.7%, while that of inorganics rose 1.6% from 1989

Marc S. Reisch,
C&EN Northeast News Bureau

Although the economic slowdown of 1990 hurt production of U.S. chemical industry customers such as auto makers and housing and office builders, U.S. chemical production itself actually recovered from a significant slowdown in 1989.

According to C&EN's annual ranking of the 50 largest volume chemical products, total production in that group increased a modest 2% in 1990 from 1989. Production reached an all-time high of 626 billion lb, significantly better than the 613 billion lb in 1989, which was just 0.2% more than in 1988.

According to the Federal Reserve Board, chemical production perked along with a seasonally adjusted 3.1% rise between the fourth quarter of 1989 and the fourth quarter of 1990. By comparison, the Federal Reserve Board figures show that between the fourth quarter of 1988 and the fourth quarter of 1989, chemical production increased 2.2% despite the increases in industry capacity brought on during that year.

Most of the increased production in 1990 took place during the first and second quarters prior to the Iraqi invasion of Kuwait, when chemical production increased at a seasonally adjusted 4.8% in the first quarter of 1990 and 4.4% in the second quarter. However, following the invasion, chemical production, reacting to increases in energy and feedstock prices at the time, dropped off. Chemical production increased at a seasonally adjusted rate of 2.9% in the third quarter of 1990 and dropped back further to a 0.3% increase in the fourth quarter.

To judge by the depressed Federal Reserve statistics regarding production levels for the transportation, construction, appliance, carpeting, and furniture industries during 1990, all major users of chemical products, domestic demand could not account for chemical production

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates, all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1990. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 14 are different in some cases from those published in last year's Top 50 article. The final reports also can affect the rankings of chemicals. For the table on page 14, the 1989 ranking of 11 chemicals is different from last year's listing (C&EN, April 9, 1990, page 11).

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from the chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster includes basic inorganic chemicals but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead burned) dolomite is excluded in lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

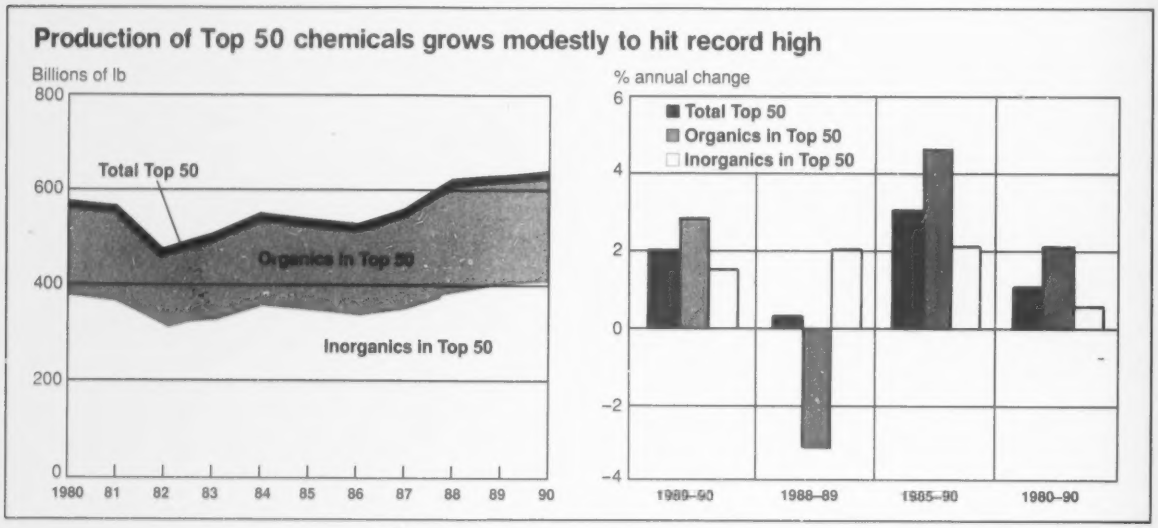
There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included.

Production figures are published by the government in a variety of units—pounds, tons, cubic feet, gallons, metric tons, and, most recently, kilograms and liters. Where the latter two units are used, they have been converted, where appropriate, into the common units that the government and industry have historically used as points of reference. To provide an accurate ranking and to make comparison of production volumes easier, C&EN lists production not only in common units, but converted to pounds.

Top 50 chemical production totaled about 626 billion lb last year

Rank 1990	Rank 1989[a]		Billions of lb 1990	Billions of lb 1989	Common units[b] 1990	Common units[b] 1989	Average annual growth 1989–90	1988–89	1985–90	1980–90
1	1	Sulfuric acid	88.56	86.60	44,281 tt	43,301 tt	2.3%	2.8%	2.1%	0 %
2	2	Nitrogen	57.32	53.91	791 bcf	744 bcf	6.3	3.0	3.8	5.1
3	3	Oxygen	38.99	37.42	471 bcf	452 bcf	4.2	0	3.7	0.9
4	4	Ethylene	37.48	34.95	37,480 mp	34,953 mp	7.2	−6.0	4.7	2.7
5	5	Lime[c]	34.80	34.36	17,400 tt	17,178 tt	1.3	0.7	1.9	−0.9
6	6	Ammonia	33.92	32.72	16,958 tt	16,362 tt	3.6	−2.7	−0.4	−1.5
7	7	Phosphoric acid	24.35	23.47	12,175 tt	11,735 tt	3.7	0.5	3.0	1.2
8	9	Sodium hydroxide	23.38	20.98	11,688 tt	10,492 tt	11.4	−0.3	1.4	0.1
9	10	Propylene	22.12	20.23	22,117 mp	20,229 mp	9.3	−4.7	8.2	4.9
10	8	Chlorine	21.88	22.83	10,942 tt	11,413 tt	−4.1	1.4	1.0	−0.4
11	11	Sodium carbonate[d]	19.85	19.83	9,925 tt	9,915 tt	0.1	2.9	3.1	1.8
12	13	Urea[e]	15.81	15.93	7,905 tt	7,963 tt	−0.7	0.6	3.4	0.1
13	12	Nitric acid	15.50	16.70	7,749 tt	8,349 tt	−7.2	4.5	1.0	−1.7
14	14	Ammonium nitrate[f]	14.21	15.74	7,107 tt	7,871 tt	−9.7	4.9	1.0	−2.5
15	15	Ethylene dichloride	13.30	13.68	13,301 mp	13,675 mp	−2.7	5.0	1.9	1.8
16	16	Benzene	11.86	11.67	1,610 mg	1,585 mg	1.6	−0.5	4.8	−2.2
17	17	Carbon dioxide[g]	10.98	10.68	5,491 tt	5,339 tt	2.8	5.6	1.9	6.2
18	18	Vinyl chloride	10.65	9.62	10,652 mp	9,618 mp	10.8	6.2	2.4	5.1
19	19	Ethylbenzene	8.99	9.22	8,988 mp	9,223 mp	−2.5	−7.1	4.0	1.6
20	21	Styrene	8.02	8.13	8,018 mp	8,129 mp	−1.4	−9.5	1.0	1.6
21	22	Methanol	7.99	7.14	7,987 mp	7,139 mp	11.9	−12.3	9.8	1.1
22	20	Terephthalic acid[h]	7.69	8.31	7,692 mp	8,309 mp	−7.4	−18.8	3.5	2.4
23	23	Formaldehyde[i]	6.41	6.37	6,413 mp	6,370 mp	0.7	1.4	2.7	1.4
24	30	Methyl *tert*-butyl ether[j]	6.30	4.98	6,302 mp	4,976 mp	26.6	−12.4	27.2	na
25	25	Toluene[k]	6.10	5.84	841 mg	805 mg	4.5	−8.0	3.8	−1.9
26	26	Xylene	5.70	5.80	791 mg	805 mg	−1.7	5.8	1.4	−1.4
27	29	Ethylene oxide	5.58	5.32	5,581 mp	5,322 mp	4.9	−10.6	0.6	0.7
28	28	*p*-Xylene	5.20	5.49	5,201 mp	5,494 mp	−5.3	−1.9	1.7	2.1
29	27	Ethylene glycol	5.03	5.50	5,028 mp	5,499 mp	−8.6	−0.3	3.8	1.4
30	31	Ammonium sulfate	4.99	4.69	2,495 tt	2,347 tt	6.3	0.6	3.6	1.6
31	24	Hydrochloric acid	4.68	6.35	2,341 tt	3,177 tt	−26.3	20.3	−3.5	−2.1
32	32	Cumene	4.31	4.54	4,312 mp	4,535 mp	−4.9	1.8	5.2	2.2
33	34	Acetic acid	3.76	3.83	3,756 mp	3,826 mp	−1.8	21.1	5.3	2.4
34	35	Potash[l]	3.62	3.52	1,640 tmt	1,595 tmt	2.8	4.9	4.8	−3.1
35	33	Phenol[m]	3.51	3.89	3,512 mp	3,893 mp	−9.8	9.3	4.8	3.2
36	36	Propylene oxide	3.20	3.20	3,200 mp	3,200 mp	0	2.9	5.9	6.1
37	37	Butadiene[n]	3.16	3.09	3,156 mp	3,094 mp	2.0	−2.4	6.2	1.2
38	39	Acrylonitrile	3.03	2.61	3,029 mp	2,608 mp	16.1	0	5.2	5.2
39	38	Carbon black	2.87	2.91	2,868 mp	2,913 mp	−1.5	−0.1	2.2	1.2
40	42	Vinyl acetate	2.55	2.47	2,546 mp	2,470 mp	3.1	−3.6	3.8	2.8
41	43	Cyclohexane	2.47	2.39	2,468 mp	2,389 mp	3.3	4.0	8.3	2.3
42	41	Aluminum sulfate	2.42	2.49	1,208 tt	1,244 tt	−2.9	1.0	−1.0	−0.6
43	40	Acetone	2.22	2.50	2,221 mp	2,497 mp	−11.1	8.4	4.4	0.7
44	44	Titanium dioxide	2.16	2.20	1,079 tt	1,101 tt	−2.0	7.7	4.6	4.2
45	46	Sodium silicate	1.76	1.67	878 tt	834 tt	5.3	2.7	4.9	0.9
46	47	Adipic acid	1.64	1.64	1,640 mp	1,640 mp	0	2.5	2.5	1.1
47	48	Sodium sulfate[o]	1.47	1.51	733 tt	755 tt	−2.9	−7.6	−2.4	−4.3
48	45	Calcium chloride[p]	1.38	1.92	690 tt	962 tt	−28.3	32.0	−2.9	−3.5
48	49	Isopropyl alcohol	1.38	1.43	1,380 mp	1,432 mp	−3.6	3.1	2.2	−2.8
48	50	Caprolactam	1.38	1.31	1,380 mp	1,312 mp	5.2	4.0	5.0	4.3
TOTAL ORGANICS			216.82	211.07			2.7%	−3.0%	4.6%	2.1%
TOTAL INORGANICS			409.07	402.51			1.6%	2.0%	2.1%	0.5%
GRAND TOTAL			625.89	613.58			2.0%	0.2%	2.9%	1.0%

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic. e 100% basis. f Original solution. g Liquid and solid only. h Includes both acid and ester without double counting. i 37% by weight. j Production data for earlier years unavailable. k All grades. l K_2O basis. m Synthetic only. n Rubber grade. o High and low purity. p Solid and liquid. na = not available.



increases. And while it is true that automobile manufacturers are using more plastics and chemical adhesives per vehicle, the use of chemical products still has not increased so much that it would so significantly outstrip auto and truck production, which declined 11% between the fourth quarter of 1989 and the fourth quarter of 1990.

Just like 1989, significant exports of U.S.-produced chemicals can account in large measure for how well the U.S. chemical industry has done by comparison with other major industries. U.S. chemical exports were $37.6 billion in 1989, according to the U.S. Bureau of the Census. Based in part on government data along with industry projections, the Chemical Manufacturers Association estimates that U.S. exports rose again in 1990 to $38 billion.

The trend of growing U.S. chemical exports just may continue to sustain production growth in 1991. Chevron, Exxon Chemical, and Mitsubishi plan to expand an ethylene import terminal allowing the partners to export product from Chevron U.S.A.'s Galena Park Terminal on the Houston Ship Channel (C&EN, March 25, page 7). When it comes on line in the third quarter of 1991, the facility will be able to export up to 400,000 tons annually.

Among the largest volume chemicals produced in the U.S., sulfuric acid remains at the top with total production of 88.6 billion lb, up 2.3% from 1989. The increase in production was not quite so good as the 2.8% rise the previous year. For 1990, nitrogen continues to rank a distant number two, with production at 57.3 billion lb, up 6.3% from 1989. Nitrogen production grew at a much faster pace than it did in 1989 when output was up only 3%.

Of the Top 50, the 29 organic chemicals accounted for some 35% of total production, compared with 34% in 1989. The combined organics production increased 2.7% in 1990 from the previous year, after a 3% decline in 1989. Over the five-year period 1985-90, combined production of organic chemicals among the Top 50 increased an average of 4.6% a year. But historically, their output has grown at a slower pace. Between 1980 and 1990, combined output of organic chemicals among the Top 50 grew at a compound annual rate of 2.1% a year.

While organic chemical production rebounded in 1990, inorganic chemical production slowed compared with the previous year. Combined output of inorganics on the list rose only 1.6% from the previous year, following a 2% increase in 1989. Over the five-year period from 1985 to 1990, combined production of inorganic chemicals grew at an average annual rate of 2.1% a year. Like the organics group, inorganics production historically has grown at a slower pace: 0.5% between 1980 and 1990.

For organic chemicals, 1990 growth was led by methyl tert-butyl-ether (MTBE), production of which rose 27% from 1989 to 6.3 billion lb. As a result, MTBE moved to 24th place on the 1990 list from 30th place on the 1989 list. Acrylonitrile production also grew at a double-digit pace, up 16% in 1990 to 3 billion lb. Acrylonitrile's strong growth moved it to 38th place on the Top 50 list from 39th place the previous year. Vinyl chloride production grew 11% from 1989 to 10.7 billion lb, but its growth was not sufficient to improve its ranking from 18th place.

Only one organic chemical registered a double-digit decline in 1990 production: Acetone output dipped 11% to 2.2 billion lb. The decrease moved acetone down to 43rd place from 40th place the previous year.

For inorganic chemicals, 11 of the 21 on the Top 50 list posted production increases, led by sodium hydroxide with 11% to reach 23.4 billion lb in 1990. The gain pushed sodium hydroxide to eighth place from ninth in the 1989 ranking.

Two inorganics—nitrogen and ammonium sulfate—tied for the next largest gain of 6.3%. Nitrogen production rose to 57.3 billion lb, keeping it in second place in the ranking; and ammonium sulfate production rose to 5 billion lb, moving it up to 30th place from 31st in 1989.

Sodium silicate also did well, with production rising 5.3% from 1989 to 1.8 billion lb, boosting it to 45th place from 46th the previous year.

Despite these gains, production declined for almost half of the inorganics, some declining significantly. The biggest underachiever was calcium chloride, production of which is estimated to have declined 28% in 1990. Calcium chloride thus slipped to 48th place from 45th in 1989. The large swing in calcium chloride production may not be an entirely accurate picture because such a large part of the data on which the Bureau of Mines depends is based on an estimate. A statistician for the Bureau of Mines notes that despite the swings in production reports, the figures reported were the best estimates the government could make because it could not get a good figure from Dow Chemical and thus had to rely on industry estimates.

Also showing a double-digit decline in production was hydrochloric acid, with output dropping 26% in 1990 to 4.7 billion lb. In 1989, hydrochloric acid production rose 20%.

All in all, of the Top 50 chemicals, production of 26 of them increased in 1990. By contrast production of 30 increased in 1989. Total production of the Top 50 chemicals, at 626 billion lb, was 35% higher than the decade low of 464 billion lb registered in 1982.

For the Top 50 group, composite output increased at a compound annual rate of 2.9% between 1985 and 1990. Long-term growth for the group as a whole was at an even slower pace. Between 1980 and 1990, Top 50 production grew at an average annual rate of 1%.

Looking at growth over the past 10 years, 34 of the Top 50 chemicals have recorded overall production increases. The best long-term growth performer has been carbon dioxide, output of which grew at an annual compound rate of 6.2% during the period. Propylene oxide turned in the next best performance with long-term growth of 6.1%. Other chemicals with sizable annual growth rates were acrylonitrile, up 5.2%; nitrogen and vinyl chloride, both up 5.1%; and propylene, up 4.9%. Sodium sulfate registered the largest decline over the past 10 years, with output falling at a compound annual rate of 4.3%. □

Plastics lead polymer output recovery

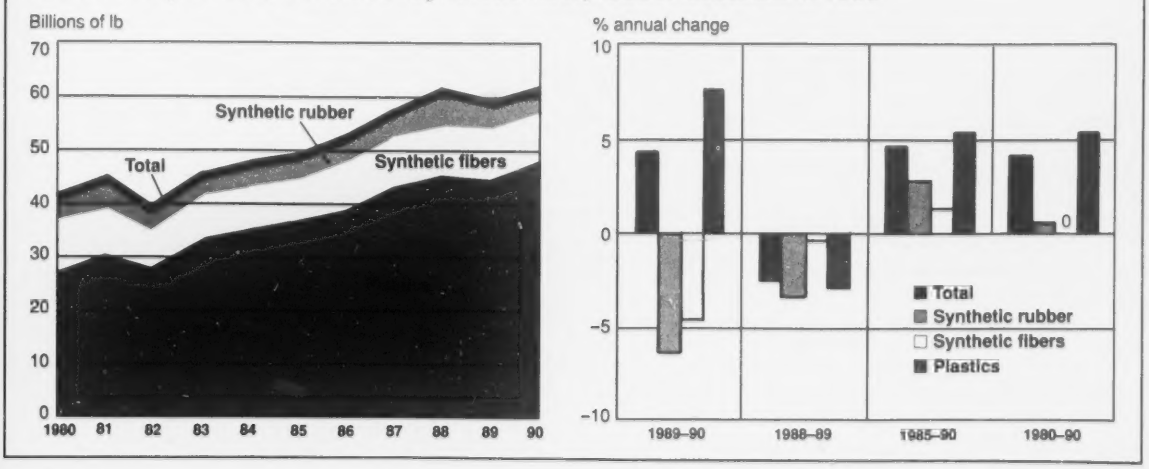
Overall U.S. production of commercial polymers, including plastics, synthetic fibers, and synthetic rubber, increased 4.3% in 1990 following a 2.3% decline in 1989. As a result, output, which faltered in 1989 following seven years of growth, resumed growth. Total 1990 polymer output reached 61.6 billion lb, a new record, topping the 60.5 billion lb record set in 1988.

Plastics production increased at such a fast rate, it led a recovery for a category that otherwise sustained production declines. As a group, plastics account for more than three quarters of the polymer category's production total. The 7.3% production rise for plastics helped overcome the 6.5% decline in fibers and 4.6% decline in synthetic rubber production in 1990. The plastics group recovered from a 2.5% production decline in 1989.

Production of thermoplastic resins grew at a rate of 8.6% in 1990 following a decline of 2.5% in 1989. Thermosetting resins, off 0.6%, performed better in 1990 compared with 1989, when their production declined 2.8%.

Among the thermoplastics, low-density polyethylene production grew at an annual rate of 15.3% in 1990, recovering nicely from a 6.8% drop in 1989 compared with the previous year. Polypropylene turned in the next best performance in 1990, with output up 14.9% in 1990 compared with a 0.5% decline in 1989. Production of polyvinyl chloride and copolymers was up 7.2%, and output

Plastics output rose, but that of synthetic fiber, rubber declined in 1990



Total polymer production pushed past 61 billion lb in 1990

	Billions of lb		Common units					Average annual growth			
	1990	1989	1990	1989	1988	1985	1980	1989–90	1988–89	1985–90	1980–90
PLASTICS (millions of lb)											
Thermosetting resins	**6.36**	**6.41**	**6,364**	**6,405**	**6,588**	**5,631**	**4,093**	**−0.6%**	**−2.8%**	**2.5%**	**4.5%**
Phenol and other tar acid resins	2.95	2.88	2,946	2,879	3,066	2,621	1,499	2.3	−6.1	2.4	7.0
Urea resins	1.50	1.48	1,496	1,476	1,425	1,210	1,165	1.4	3.6	4.3	2.5
Polyesters (unsaturated)	1.22	1.32	1,221	1,319	1,404	1,223	947	−7.4	−6.1	0	2.6
Epoxies (unmodified)	0.50	0.51	499	509	486	385	315	−2.0	4.7	5.3	4.7
Melamine resins	0.20	0.22	202	222	207	192	167	−9.0	7.2	1.0	1.9
Thermoplastic resins	**41.93**	**38.62**	**41,928**	**38,617**	**39,608**	**31,525**	**24,335**	**8.6%**	**−2.5%**	**5.9%**	**5.6%**
Low-density polyethylene	11.18	9.70	11,176	9,695	10,397	8,889	7,291	15.3	−6.8	4.7	4.4
PVC and copolymers	9.09	8.48	9,088	8,478	8,350	6,772	5,470	7.2	1.5	6.1	5.2
High-density polyethylene	8.33	8.10	8,334	8,102	8,400	6,671	4,405	2.9	−3.5	4.6	6.6
Polystyrene[a]	5.01	5.10	5,012	5,104	5,187	4,054	3,521	−1.8	−1.6	4.3	3.6
Polypropylene	8.32	7.24	8,318	7,238	7,274	5,139	3,648	14.9	−0.5	10.1	8.6
TOTAL[b]	**48.29**	**45.02**	**48,292**	**45,022**	**46,196**	**37,156**	**28,428**	**7.3%**	**−2.5%**	**5.4%**	**5.4%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.50**	**0.58**	**502**	**580**	**614**	**558**	**806**	**−13.4%**	**−5.5%**	**−2.1%**	**−4.6%**
Rayon[c]	0.30	0.36	296	363	400	353	490	−18.5	−9.3	−3.5	−4.9
Acetate[d]	0.21	0.22	206	217	214	205	316	−5.1	1.4	0.1	−4.2
Noncellulosics[b]	**8.18**	**8.52**	**8,175**	**8,515**	**8,526**	**7,564**	**7,874**	**−4.0%**	**−0.1%**	**1.6%**	**0.4%**
Polyester	3.19	3.59	3,193	3,594	3,680	3,341	3,989	−11.2	−2.3	−0.9	−2.2
Nylon[e]	2.66	2.74	2,661	2,740	2,670	2,343	2,358	−2.9	2.6	2.6	1.2
Olefin[f]	1.82	1.64	1,815	1,639	1,588	1,249	748	10.7	3.2	7.8	9.3
Acrylic[g]	0.51	0.54	506	542	588	631	779	−6.6	−7.8	−4.3	−4.2
TOTAL[b]	**8.68**	**9.10**	**8,677**	**9,095**	**9,140**	**8,122**	**8,680**	**−4.6%**	**−0.5%**	**1.3%**	**0 %**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[h]	1.88	1.93	853	874	909	735	1,074	−2.4	−3.9	3.0	−2.3
Polybutadiene	0.89	0.91	403	411	407	330	311	−1.9	1.0	4.1	2.6
Ethylene-propylene	0.56	0.57	256	260	263	215	144	−1.5	−1.1	3.6	5.9
Nitrile	0.12	0.15	56	69	76	53	63	−18.8	−9.2	1.1	−1.2
Other[i]	1.20	1.43	546	648	679	505	423	−15.7	−4.6	1.6	2.6
TOTAL[b]	**4.66**	**4.99**	**2,114**	**2,262**	**2,334**	**1,838**	**2,015**	**−6.5%**	**−3.1%**	**2.8%**	**0.5%**

a No longer includes acrylonitrile-butadiene-styrene, or styrene acrylonitrile resins; historical data are restated. b Totals are for those products listed and may not add because of rounding. c Based on C&EN estimates. d Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. e Excludes aramid after 1982. f Includes olefin film, olefin fiber, spun-bonded polypropylene, and vinyon. g Includes modacrylic. h Excludes high-styrene latex. i Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Fiber Economics Bureau, Rubber Manufacturers Association

of high-density polyethylene rose 2.9% in 1990, compared with a 1.5% rise and a 1.6% decline, respectively, in 1989. Only polystyrene registered a production decline among the thermoplastics in 1990, down 1.8% after a 1.6% decline in 1989.

In the thermosetting resins category, phenol and other tar acid resins staged a modest growth recovery to 2.3% in 1990 following a 6.1% decline in 1989. Urea resins output rose only 1.4% in 1990 compared with a 3.6% rise in 1989. Other thermosetting resins fared poorly in 1990. Melamine resins, which showed good growth in 1989, led the decline in 1990. Their production was off 9% in 1990 compared with a 7.2% gain in 1989. Unsaturated polyesters output declined 7.4% in 1990 and unmodified epoxies output declined 2%. In 1989, polyester production declined 6.1% and epoxies rose 4.7%.

The synthetic rubber segment's decline accelerated in 1990. Output dropped 6.5% in 1990 compared with a 3.1% decline in 1989. Production totaled 4.7 billion lb in 1990 compared with 5 billion lb in 1989. None of the synthetic rubber categories registered production increases in 1990. The best performer, if indeed it could be called such, was ethylene-propylene type polymers, production of which declined 1.5% in 1990 compared with a 1.1% decline in 1989. Polybutadiene production was down 1.9%, following a 1.0% decline in 1989, while styrene-butadiene was off 2.4% after a 3.9% decline in 1989. Nitrile rubber showed the largest decline in 1990, down 19%, while the category listed as other, and including neoprene, butyl, polyisoprene and other rubbers, declined 16%.

While synthetic fiber output declined marginally in 1989 from 1988, the economic slowdown of 1990 had a severe impact on the category. Overall fiber output declined 4.6% in 1990. While imported textiles continued to put pressure on domestic textile output and fiber use, consumer preference for cotton also had an impact on synthetic fiber production. Among the noncellulosics, only olefin output appeared to do well, up 11% in 1990.

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